



GANIL

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G A N I L

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Résumé.— Le projet Ganil, actuellement en construction à Caen, est constitué principalement de deux cyclotrons identiques isochrones et à secteurs séparés de $K = 400$. Le principe de l'accélérateur et les performances prévues sont présentés.

Abstract — The project Ganil which is under construction at Caen consists essentially of two identical isochronous separated sector cyclotrons with $K = 400$. The principle of the accelerator and the expected performances are presented.

1. INTRODUCTION

The french nuclear physicist community published, in 1973, a report [1] on nuclear physics with heavy ions and on the construction of Ganil (Grand Accélérateur National d'Ions Lourds). In order to allow the study of the different kinds of phenomena schematically indicated in fig. 1, Ganil

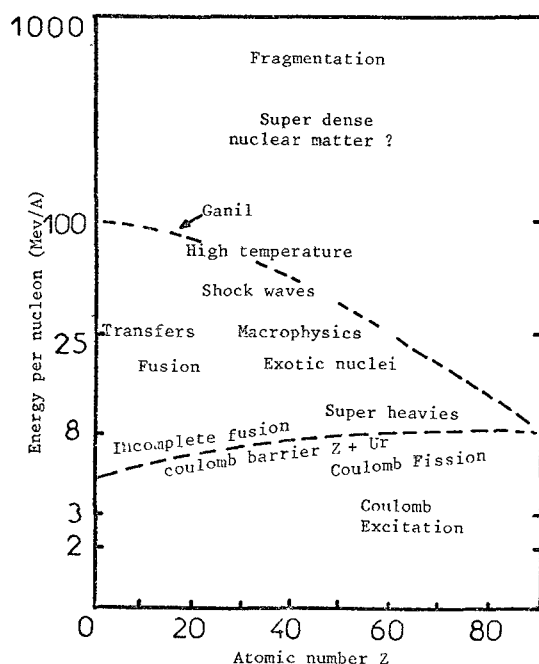


Fig. 1 - Different kinds of phenomena which might be studied with heavy ion beams depending of incident energies (in MeV per nucleon with laboratory system) for different atomic number Z of projectiles.

must be capable of producing intense and high quality beams for all available atomic ions with energies as shown by the dashed line. Furthermore energy precision for heavy ion nuclear research might reach few 10^{-4} for $A < 60$ projectiles and about 10^{-3} for $A > 60$ ions; so the beam quality of Ganil has to fulfill these requirements. The chosen configuration of the accelerator is two identical isochronous separated sector cyclotrons whose parameters would be discussed in section 2. The first cyclotron (CSS1) is acting as an injector for the second one (CSS2) after that ions are passing through a stripper in order to increase their charge state (Fig. 2). In front of CSS1, a small cyclotron C_0 is the source of the accelerator.

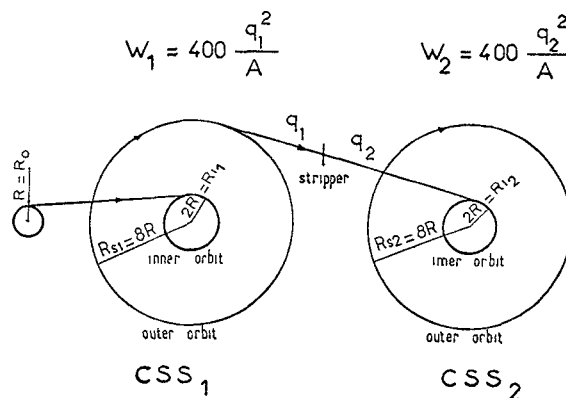


Fig. 2 - Schematic diagram of the accelerator

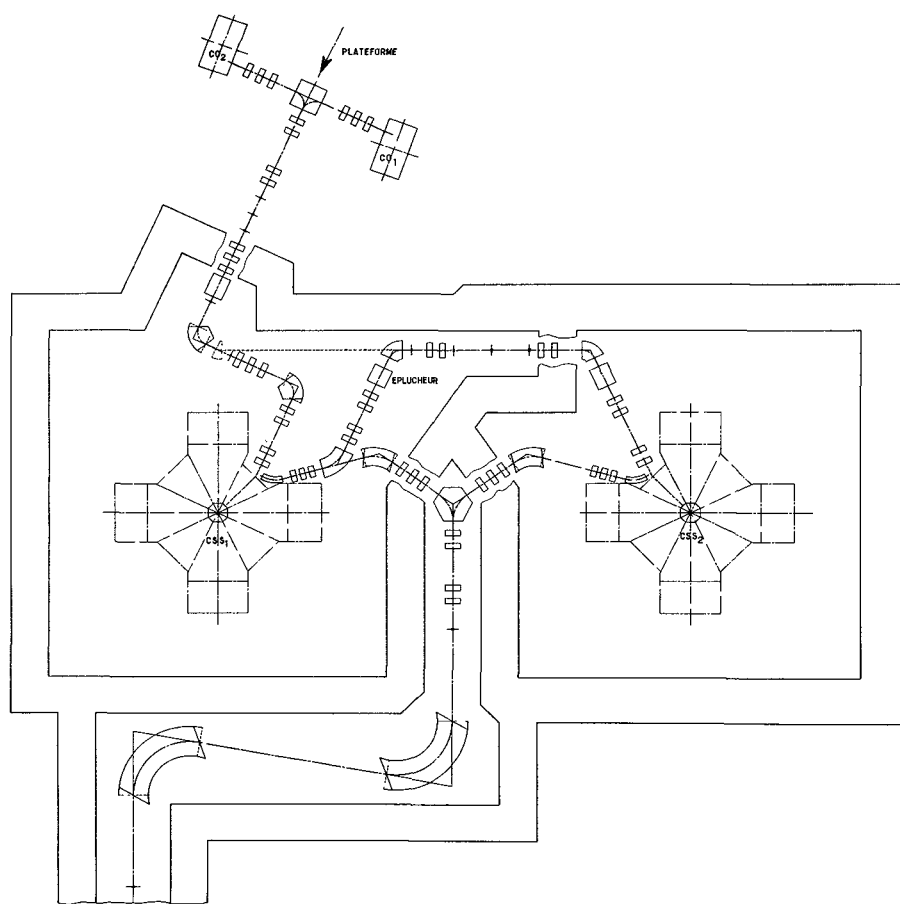


Fig. 3 - Plan view of the relative position of the cyclotrons and transportation elements

Figure 3 shows some more details on the beam lines and transportation elements.

In may 1975, after one year and a half of calculations on particle dynamics in such accelerating system, a second report [2] was published defining more precisely the expected performances of Ganil which will be presented briefly in section 3. The set up of this accelerator involves mainly conventional techniques. In september 1975, Ganil was authorized for construction at Caen and the first beam is currently expected in 1981.

2. CHOICE OF THE PARAMETERS

2.1. CSS2. To accelerate atomic ions with charge to mass ratio $\epsilon = q/A = 1/2$ which is possible for light heavy ions, up to 100 MeV/A, the constant K of a cyclotron ($W = Kq^2/A^2$) must be equal to 400. Since $K \propto B^2 \rho^2$, then for a magnetic field $B = 1.6$ tesla which is the best value which can be achieved in a large sector focused magnet, the magnetic radius ρ is 1.8 meter corresponding to a geometri-

cal radius $R_{S2} \approx 3$ meters (the sector magnet has an angular aperture $2\alpha = 52^\circ$ for focalisation requirements).

It is not possible to inject in the center of CSS2 at less than $R_{i2} = 0.70$ meter because of construction conditions and magnetic field quality ; so the value $R_{i2} = 0.75$ meter was chosen. Under these conditions, the energy gain of CSS2, $G_2 = (R_{s2}/R_{i2})^2 = 16$ and since $G = W_{s2}/W_{i2}$, then $W_{i2}(\bar{\epsilon})$ is fixed.

One notices that for very heavy ions like uranium, $\bar{\epsilon} \approx 0.14$ and $W \approx 8$ MeV/A can then be obtained.

2.2. CSS1. Presently, sources are far to give ions with charge states required to be accelerated at maximum energy in CSS2. It is interesting to notice that at energies of one to few MeV/A, the mean charge states of ions through a stripper is increased by a factor 4 ($\epsilon_2 = 4\epsilon_1$). Since we know that $W_{s1}(\epsilon_1) = W_{i2}(\epsilon_2) = W_{s2}/16(\epsilon_2)$ then

$$(B_p)_{CSS1} = (B_p)_{CSS2}$$

It is advantageous economically to construct two identical cyclotrons ; then using the same magnetic field in both two CSS, we have :

$$R_{s1} = R_{s2} = 4 R_{i1} = 4 R_{i2}$$

2.3. Cyclotron Injector C₀. In front of CSS1, the injector C₀ is a small cyclotron C₀ which must furnish ion beams with charge state q₁ given by a PIG source and with the matching energy $W_o = W_{i1} = W_{s1}/16$. It is interesting for economical reasons to construct the smaller injector as possible and so the mean outer orbit was fixed as : $R_{C_o} = R_{i1}/2 = 0.375$ m. The induction B in C₀ ranges between 0.8 to 1.91 tesla. The main characteristics of C₀ are presented in table I

Table I

	Unity	
Energy	keV/A	15-390
Max. beam intensity		
light ions	p.p.s	10^{+14}
heavy ions	p.p.s	10^{+13}
HF width of particle packs	degree	15°
Intrinsic energy spread $\Delta W/W$		10^{-2}
Horizontal emittance at 390 keV mm rad		45 π
Vertical emittance at 390 keV mm rad		135 π

2.4. Coupling of the cyclotrons. The rf coupling between C₀, CSS1 and CSS2 results from the relative geometrical conditions of outer and inner orbits. According to the relation $f^{rev} = Bq/2\pi m$, the revolution frequencies of particles are as follows for the same velocity v :

$$2f_{C_o}^{rev} = 4f_{CSS1}^{rev} = f_{CSS2}^{rev}$$

since the magnetic field in C₀ is twice the average field in CSS1 and the charge in CSS2 is multiplied by 4.

To avoid loss of particle packs between CSS1 and CSS2, it is necessary to match them in synchronism.

$$f_{C_o}^{HF} = f_{CSS1}^{HF} = f_{CSS2}^{HF}$$

Then harmonic numbers are like :

$$2h_{C_o} = h_{CSS1} = 4h_{CSS2}$$

For the chosen W_{s2} and R_{s2} values, the f_{CSS2}^{rev} range is :

$$1.4 \text{ MHz} \leq f_{CSS2}^{rev} \leq 6.8 \text{ MHz.}$$

Then by fixing $h_{CSS2} = 2$ or 4 , it follows that $h_{CSS1} = 8$ or 16 and $h_{C_o} = 4$ or 8 . The frequency range of the HF system is $5.6 \text{ MHz} \leq f^{HF} \leq 13.6 \text{ MHz}$.

3. BEAM QUALITY

Intrinsic beam properties expected [2] from Ganil are shown in table II. A flat-topping will be used to reach them especially for light ions ($A < 60$).

Table II

	Intensity (p.p.s)	$\frac{\Delta E}{E}$	Emittance at 10 MeV/A (mm \times mrad)	
			horiz.	vert.
$A \lesssim 60$	2×10^{11}	$\pm 2 \times 10^{-4}$	5	50
	10^{12}	$\pm 2 \times 10^{-4}$	50	50
	10^{13}	10^{-3}	100	100
$A \gtrsim 60$	10^{11}	10^{-3}	100	100

Interdependence between beam intensity, energy resolution, horizontal and vertical beam emittance are presented for different cases. Beam quality can then be varied depending on experimental requirements.

The expected beam energies are presented for some projectiles along the mass table in fig. 4. The maximum energy ranges from 100 MeV/A from carbon to silicon decreasing with increasing projectile atomic number (around 50 MeV/A for krypton and 10 MeV/A for uranium). The operational flexibility allows to continuously vary the energy from the maximum down to 4 MeV/A. It is also possible to run only one cyclotron and to obtain energy of 40 MeV/A for carbon (fig. 4) decreasing up to 8 MeV/A for argon with higher beam intensities as shown in table II because there will have no stripping.

We acknowledge Dr. Beck and Dr Chabert for providing us figures 3 and 4.

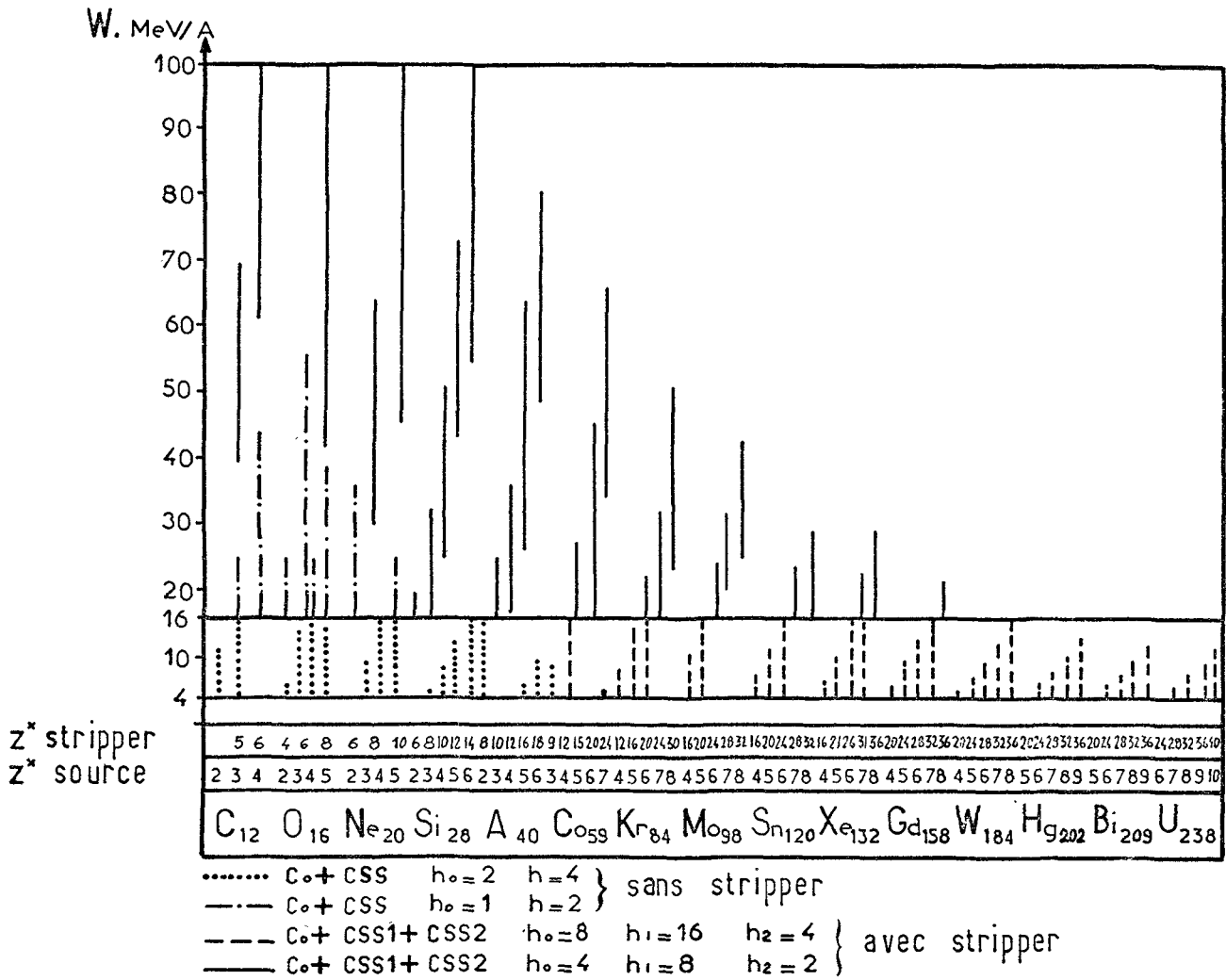


Fig. 4

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